

## CLAIMS

1. A ceramic composite, said ceramic composite comprising:
  - a) a mesoporous matrix, said mesoporous matrix comprising a ceramic matrix and having a plurality of pores dispersed therethrough;
  - b) a plurality of inorganic crystalline nanodispersoids dispersed throughout said mesoporous matrix and disposed within said plurality of pores, wherein each of said plurality of nanodispersoids has at least one dimension of less than about 100 nm, wherein said mesoporous matrix imposes an ordered structure around each of said nanodispersoids.
2. The ceramic composite according to Claim 1, wherein said ceramic composite is both thermally and structurally stable up to about 1000°C.
3. The ceramic composite according to Claim 2, wherein said ceramic composite is both thermally and structurally stable up to about 1500°C.
4. The ceramic composite according to Claim 1, wherein said matrix comprises at least one transition metal oxide.
5. The ceramic composite according to Claim 4, wherein said transition metal oxide is one of hafnia and zirconia.
6. The ceramic composite according to Claim 4, wherein said transition metal oxide is stable up to about 1000°C.
7. The ceramic composite according to Claim 4, wherein said transition metal oxide is stable up to about 1500°C.
8. The ceramic composite according to Claim 1, wherein said matrix comprises silica.
9. The ceramic composite according to Claim 1, wherein said plurality of nanoparticles comprises at least one inorganic oxide.

10. The ceramic composite according to Claim 9, wherein said at least one inorganic oxide comprises at least one group IVB metal oxide.

11. The ceramic composite according to Claim 10, wherein said at least one group IVB metal oxide is one of hafnia, zirconia, and combinations thereof.

12. The ceramic composite according to Claim 9, further comprising at least one inorganic host lattice disposed in each of said plurality of nanoparticles.

13. The ceramic composite according to Claim 12, wherein said inorganic host lattice comprises at least one light activating species, wherein said at least one light activating species has a characteristic emission spectra.

14. The ceramic composite according to Claim 12, wherein said at least one light activating species comprises at least one of  $\text{Ni}^{2+}$ ,  $\text{Ti}^{3+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Cr}^{4+}$ ,  $\text{Mn}^{5+}$ ,  $\text{Pr}^{3+}$ ,  $\text{Nd}^{3+}$ ,  $\text{Eu}^{3+}$ ,  $\text{Ho}^{3+}$ ,  $\text{Tm}^{3+}$ ,  $\text{Yb}^{3+}$ , and  $\text{Ce}^{3+}$ .

15. The ceramic composite according to Claim 12, wherein said inorganic host lattice comprises at least one of yttria, europia, ceria, yttrium silicate, gadolinium silicate, lutetium silicate, and combinations thereof.

16. The ceramic composite according to Claim 1, wherein said ordered structure is a bidimensional hexagonal structure.

17. The ceramic composite according to Claim 1, wherein said ordered structure is a cubic structure.

18. The ceramic composite according to Claim 1, wherein said ordered structure is a lamellar structure.

19. An array of ceramic nanoparticles templated within a mesoporous network, wherein said mesoporous network forms an ordered structure surrounding each of said ceramic nanoparticles in said array.

20. The array according to Claim 19, wherein said ordered structure is a bidimensional hexagonal structure.

21. The array according to Claim 19, wherein said ordered structure is a cubic structure.

22. The array according to Claim 19, wherein said ordered structure is a lamellar structure.

23. The array according to Claim 19, wherein said each of said nanoparticles comprises at least one inorganic oxide.

24. The array according to Claim 23, wherein said at least one inorganic oxide comprises at least one group IVB metal oxide.

25. The array according to Claim 24, wherein said at least one group IVB metal oxide is one of hafnia and zirconia.

26. The array according to Claim 24, further comprising at least one inorganic host lattice disposed in each of said plurality of nanoparticles.

27. The array according to Claim 26, wherein said inorganic host lattice comprises at least one light activating species, wherein said at least one light activating species has a characteristic emission spectra.

28. The array according to Claim 26, wherein said at least one light activating species comprises at least one of  $\text{Ni}^{2+}$ ,  $\text{Ti}^{3+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Cr}^{4+}$ ,  $\text{Mn}^{5+}$ ,  $\text{Pr}^{3+}$ ,  $\text{Nd}^{3+}$ ,  $\text{Eu}^{3+}$ ,  $\text{Ho}^{3+}$ ,  $\text{Tm}^{3+}$ ,  $\text{Yb}^{3+}$ , and  $\text{Ce}^{3+}$ .

29. The array according to Claim 26, wherein said inorganic host lattice comprises at least one of yttria, europia, ceria, yttrium silicate, gadolinium silicate, lutetium silicate, and combinations thereof.

30. A ceramic composite, said ceramic composite comprising:

a) a mesoporous matrix, said mesoporous matrix comprising a ceramic matrix and having a plurality of pores dispersed therethrough, wherein said plurality of pores form a mesoporous network; and

b) an array of ceramic nanoparticles templated within said mesoporous network, wherein said mesoporous network forms an ordered structure around each of said ceramic nanoparticles in said array, wherein each of said plurality of ceramic nanoparticles has a dimension of less than about 100 nm, wherein said ceramic composite is thermally and structurally stable up to about 1000°C.

31. The ceramic composite according to Claim 30, wherein said ceramic composite is both thermally and structurally stable up to about 1500°C.

32. The ceramic composite according to Claim 30, wherein said matrix comprises at least one transition metal oxide.

33. The ceramic composite according to Claim 30, wherein said transition metal oxide is one of hafnia and zirconia.

34. The ceramic composite according to Claim 30, wherein said matrix comprises silica.

35. The ceramic composite according to Claim 30, wherein said plurality of nanoparticles comprises at least one inorganic oxide.

36. The ceramic composite according to Claim 35, wherein said at least one inorganic oxide comprises at least one group IVB metal oxide.

37. The ceramic composite according to Claim 36, wherein said at least one group IVB metal oxide is one of hafnia and zirconia.

38. The ceramic composite according to Claim 35, further comprising at least one inorganic host lattice disposed in each of said plurality of nanoparticles.

39. The ceramic composite according to Claim 38, wherein said inorganic host lattice comprises at least one light activating species, wherein said at least one light activating species has a characteristic emission spectra.

40. The array according to Claim 39, wherein said at least one light activating species comprises at least one of  $\text{Ni}^{2+}$ ,  $\text{Ti}^{3+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Cr}^{4+}$ ,  $\text{Mn}^{5+}$ ,  $\text{Pr}^{3+}$ ,  $\text{Nd}^{3+}$ ,  $\text{Eu}^{3+}$ ,  $\text{Ho}^{3+}$ ,  $\text{Tm}^{3+}$ ,  $\text{Yb}^{3+}$ , and  $\text{Ce}^{3+}$ .

41. The ceramic composite according to Claim 38, wherein said inorganic host lattice comprises at least one of one of yttria, europia, ceria, yttrium silicate, gadolinium silicate, lutetium silicate, and combinations thereof.

42. The ceramic composite according to Claim 30, wherein said ordered structure is a bidimensional hexagonal structure.

43. The ceramic composite according to Claim 30, wherein said ordered structure is a cubic structure.

44. The ceramic composite according to Claim 30, wherein said ordered structure is a lamellar structure.

45. The ceramic composite according to Claim 30, wherein said ceramic composite is formed into a near net shape.

46. The ceramic composite according to Claim 30, wherein said ceramic composite is a coating disposed on a surface of a substrate.

47. A method of making a ceramic composite comprising a mesoporous matrix, the mesoporous matrix comprising a ceramic matrix and having a plurality of pores dispersed therethrough, wherein the plurality of pores form a mesoporous network, and an array of ceramic nanoparticles templated within the mesoporous network, wherein the array forms an ordered structure within the mesoporous network, and wherein each of said plurality of ceramic nanoparticles has at least one dimension of less than about 100 nm, the method comprising the steps of:

- a) providing a ceramic matrix material;
- b) forming a templated mesoporous network within the matrix material, wherein the mesoporous network has a controlled pore size;

c) infiltrating the templated mesoporous network with an oxide precursor; and

d) converting the oxide precursor into inorganic nanoparticles within the templated mesoporous network to form the ceramic composite.

48. The method according to Claim 47, wherein the step of forming a templated mesoporous network within the matrix material comprises:

a) providing an organic silicate;

b) forming a mixture comprising the organic silicate and an aqueous solution, the aqueous solution comprising at least one primary amine, an alcohol;

c) aging the mixture for a predetermined time to form a mesoporous silica; and

d) drying the mesoporous silica to form the templated mesoporous network.

49. The method according to Claim 47, wherein the step of infiltrating the templated mesoporous network with an oxide precursor comprises:

a) providing a solution, wherein the solution comprises a predetermined concentration of the oxide precursor;

b) introducing the templated mesoporous network into the solution to form a mixture; and

c) forming a precipitate comprising the templated mesoporous network infiltrated with the oxide precursor.

50. The method according to Claim 47, wherein the step of converting the oxide precursor into inorganic nanoparticles within the templated mesoporous

network comprises calcining the oxide precursor and the templated mesoporous network.

51. The method according to Claim 47, wherein the step of calcining the oxide precursor and the templated mesoporous network comprises heating the oxide precursor and the templated mesoporous network to a temperature in a range from about 500°C to about 600°C in one of air and oxygen.

52. The method according to Claim 47, wherein the ceramic matrix material comprises at least one of a group IVB metal oxide, silica, and combinations thereof.

53. The method according to Claim 47, wherein the oxide precursor comprises at least one soluble inorganic metal salt.

54. A method of making a ceramic composite article, the ceramic composite article comprising a mesoporous matrix, the mesoporous matrix comprising a ceramic matrix and having a plurality of pores dispersed therethrough, wherein the plurality of pores form a mesoporous network, and an array of ceramic nanoparticles templated within the mesoporous network, wherein the array forms an ordered structure within the mesoporous network, and wherein each of said plurality of ceramic nanoparticles has a diameter of less than about 100 nm, the method comprising the steps of:

- a) providing a ceramic matrix material;
- b) forming a templated mesoporous network within the matrix material, wherein the mesoporous network has a controlled pore size;
- c) infiltrating the templated mesoporous network with an oxide precursor;
- d) converting the oxide precursor into inorganic nanoparticles within the templated mesoporous network to form a ceramic composite powder; and

e) forming the ceramic composite into the ceramic composite article.

55. The method according to Claim 54, wherein the step of forming a templated mesoporous network within the matrix material comprises:

- a) providing an organic silicate;
- b) forming a mixture comprising the organic silicate and an aqueous solution, the aqueous solution comprising at least one primary amine, an alcohol;
- c) aging the mixture for a predetermined time to form a mesoporous silica; and
- d) drying the mesoporous silica to form the templated mesoporous network.

56. The method according to Claim 54, wherein the step of infiltrating the templated mesoporous network with an oxide precursor comprises:

- a) providing a solution, wherein the solution comprises a predetermined concentration of the oxide precursor;
- b) introducing the templated mesoporous network into the solution to form a mixture; and
- c) forming a precipitate comprising the templated mesoporous network infiltrated with the oxide precursor.

57. The method according to Claim 54, wherein the step of converting the oxide precursor into inorganic nanoparticles within the templated mesoporous network comprises calcining the oxide precursor and the templated mesoporous network.



58. The method according to Claim 57, wherein the step of calcining the oxide precursor and the templated mesoporous network comprises heating the oxide precursor and the templated mesoporous network to a temperature in a range from about 500°C to about 600°C in one of air and oxygen.

59. The method according to Claim 57, wherein the ceramic matrix material comprises at least one of a group IVB metal oxide, silica, and combinations thereof.

60. The method according to Claim 54, wherein the oxide precursor comprises at least one soluble inorganic metal salt.

61. The method according to Claim 54, wherein the step of forming the ceramic composite into the ceramic composite article comprises at least one of cold pressing the ceramic composite, hot pressing the ceramic composite, isostatically pressing the ceramic composite, slip casting the ceramic composite, and spraying the ceramic composite to form the ceramic article.